A PROJECT REPORT

ON

# "STUDY,ANALYSIS AND DESIGN OF BOLSTER SPRING USED IN ICF RAILWAY COACHES"

Submitted to

**UNIVERSITY OF MUMBAI**

In Partial Fulfilment of the Requirement for the Award of

BACHELOR'S DEGREE IN
MECHANICAL ENGINEERING

BY


| | |
|---|---|
| SHAIKH UBAID | 15ME107 |
| SHAIKH ASIF | 15ME98 |
| ANSARI KAFIL | 15ME63 |

UNDER THE GUIDANCE OF
PROF. ASLAM HIRANI

DEPARTMENT OF MECHANICAL ENGINEERING
Anjuman-I-Islam's Kalsekar Technical Campus
SCHOOL OF ENGINEERING & TECHNOLOGY
Plot No. 2 & 3, Sector - 16, Near Thana Naka,
Khandagaon, New Panvel - 410206


**2018-2019**

AFFILIATED TO

**UNIVERSITY OF MUMBAI**

**A PROJECT REPORT**
**ON**

# "STUDY,ANALYSIS AND DESIGN OF BOLSTER SPRING USED IN ICF RAILWAY COACHES"

**Submitted to**

**UNIVERSITY OF MUMBAI**

**In Partial Fulfilment of the Requirement for the Award of**

**BACHELOR'S DEGREE IN MECHANICAL ENGINEERING**

**BY**

**SHAIKH UBAID 15ME107**
**SHAIKH ASIF 15ME98**
**ANSARI KAFIL 15ME63**

**UNDER THE GUIDANCE OF**
**PROF. ASLAM HIRANI**

**DEPARTMENT OF MECHANICAL ENGINEERING**
**Anjuman-I-Islam's Kalsekar Technical Campus**
SCHOOL OF ENGINEERING & TECHNOLOGY
**Plot No. 2 & 3, Sector - 16, Near Thana Naka,**
**Khandagaon, New Panvel - 410206**

**2018-2019**
**AFFILIATED TO**

**UNIVERSITY OF MUMBAI**

# Anjuman-i-Islam's Kalsekar Technical Campus

**Department of Mechanical Engineering**

SCHOOL OF ENGINEERING & TECHNOLOGY

**Plot No. 2 & 3, Sector - 16, Near Thana Naka,**

**Khandagaon, New Panvel - 410206**

# CERTIFICATE

This is certify that the project entitled

**"STUDY,ANALYSIS AND DESIGN OF BOLSTER SPRING USED IN ICF RAILWAY COACHES"**

submitted by

**SHAIKH UBAID 15ME107**
**SHAIKH ASIF 15ME98**
**ANSARI KAFIL 15ME63**

is a record of bonafide work carried out by them, in the partial fulfilment of the requirement for the award of Degree of Bachelor of Engineering (Mechanical Engineering) at ***Anjuman-I-Islam's Kalsekar Technical Campus, Navi Mumbai*** under the University of MUMBAI. This work is done during year 2018-2019, under our guidance.

**Date: / /**

**(Prof. ASLAM HIRANI)**
**Project Supervisor**

**(Prof. RIZWAN SHAIKH)**
**Project Coordinator**

**(Prof. ZAKIR ANSARI)**
**HOD, Mechaical Department**

**(DR. ABDUL RAZAK HONNUTAGI)**
**Director**

**External Examiner**

# Acknowledgements

We would like to take the opportunity to express my sincere thanks to my guide **ASLAM HIRANI**, Assistant Professor, Department of Mechanical Engineering, AIKTC, School of Engineering, Panvel for his invaluable support and guidance throughout my project research work. Without his kind guidance & support this was not possible.

We are grateful to him for his timely feedback which helped me track and schedule the process effectively. His time, ideas and encouragement that he gave has helped me to complete my project efficiently.

First of all, we would like to thank **Mrs. ANJALI SINHA (CWM), Mr.MAHESH DEGAONKAR (TRAINING OFFICER)** for giving us an opportunity to take training in this historical workshop.

We express my heartily gratitude to **Mr. SANJAY MAHAJAN (CI, BTC), Mr. M.A. QADRI (INST., BTC)** for their unstinting support and suggestion which gave us direction to work.

We take this opportunity to give sincere thanks to **Mr. M.A. QADRI (INST., BTC)** in “Indian railways, Matunga Carriage Workshop.” for all the help rendered during the course of this work and there. Support, motivation, guidance and appreciation.

We thank **BTC department of Indian Railways Carriage Workshop Matunga, Mumbai** for providing the opportunity to express my gratitude to all the individuals whose contribution have helped us in undergoing training and successful completion of my project at Carriage Workshop, Central Railway, Matunga, Mumbai-400019.

We would like to express deepest appreciation towards **DR. ABDUL RAZAK HONNUTAGI**, Director, AIKTC, Navi Mumbai, **Prof. ZAKIR ANSARI**, Head of Department of Mechanical Engineering and **Prof. RIZWAN SHAIKH**, Project Coordinator whose invaluable guidance supported us in completing this project.

We would also like to thank all Workshop Officials, Shop Superintendents, Staff members and faculty members for their valuable help at the time.

At last we must express our sincere heartfelt gratitude to all the staff members of Mechanical Engineering Department who helped me directly or indirectly during this course of work.

SHAIKH UBAID
SHAIKH ASIF
ANSARI KAFIL

# Project I Approval for Bachelor of Engineering

This project entitled ***"STUDY,ANALYSIS AND DESIGN OF BOLSTER SPRING USED IN ICF RAILWAY COACHES"*** by

***SHAIKH UBAID***

***SHAIKH ASIF***

***ANSARI KAFIL***

is approved for the degree of ***Bachelor of Engineering in Department of Mechanical Engineering.***

Examiners

1. .............................
2. .............................

Supervisors

1. .............................
2. .............................

Chairman

.............................

# Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Student Name
Roll Number:

# ABSTRACT

The springs used in the bogie suspension of railway coaches are compression springs. They are made of an elastic wire material formed into the shape of a helix. They are commonly referred to as a coil spring or a helical spring. They are used to store energy and subsequently release it to absorb shock or to maintain a force between contact surfaces. The spring returns to its natural length or position when unloaded.

Spring (BOLSTER) used in railway coaches have been failing prematurely much before their intended service life. The springs are made with quality materials. Visual examination shows that failure is common between first to third coils. The exact time of failure cannot be determined as the coaches come for POH after 18 months. Some cracks also negotiate during load testing. Pattern of cracks showing it may subject to transverse forces. The cracks are detected in Magna-flux testing. The present works attempt to analyze design of secondary suspension springs used in Railway coaches under transverse loading by using ANSYS 19.1 software. Stresses induced are compared with allowable stresses. Typical 13T NON-A/C coaches have been considered for the failure analysis.

**Keywords:** Bolster spring, Magna-flux testing, Ansys 19.1

# Contents

# List of Figures

# List of Tables

# Chapter 1

# ABOUT INDIAN RAILWAYS

## 1.1 Introduction to Indian Railways

Indian railways (IR) is the stated owned railway company of India Indian railway has a monopoly on the country's rail transport. It is also one of the largest and busiest rail networks in the world, transporting under 5 billion passengers and almost 650 million of freight annually. IR is the world's largest commercial or utility employer, with more than 16 million employees.

The Indian Railways route length network is spread over 115,000 km, with 12,617 passenger trains and 7,421 freight trains each day from 7,349 stations plying 23 million travellers and 3 million tonnes (MT) of freight daily. India's railway network is recognized as one of the largest railway systems in the world under single management.

The railway network is also ideal for long-distance travel and movement of bulk commodities, apart from being an energy efficient and economic mode of conveyance and transport. Indian Railways was the preferred carrier of automobiles in the country with loading from automobiles traffic growing 16 per cent in 2017-18.

| INDIAN RAILWAYS | |
|---|---|
| Headquarters | New Delhi |
| Railway Minister | Piyush Goyal |
| Network | 67,368 km(route)<br>93902 km (running track)<br>121407 km (total track) |
| Foundation | 1845-present |
| Track gauges | Broad meter, narrow |
| Revenue | Rs. 1.874 trillion<br>(US $26 billion) (2017–18) |
| Chairman Railway Board | Vinod Kumar Yadav |

**Table 1.1:** About Indian Railways

### 1.1.1 History:

A plan for a rail system in India was first put forward in 1832, but no further steps were taken for more than a decade. In 1844, the governor general of India. Lord Hardinge allowed private entrepreneurs to set up a rail system in India. Two new railway companies were created and the east India Company was asked to assist them.The first train in India becomes operation on 1852-12-22 and used for the hauling of construction material in rookie.

A year and a half later, on 1853-0.4-16, the first passenger train service was inaugurated between Boribunder Bombay and Thana. Covering a distance of 34km (21miles), it formally heralded the birth of railways in India.

The British government encouraged new railway companies backed by private investors under a scheme that would guarantee an annual return of five percent during the initial year of operation. Once established, the company would be transferred to the government, with the original company retaining operational control. The route mileage of this network was about 14,500km (9,000) miles by 1880, mostly radiating inward from the three major cities of Bombay, madras and Calcutta .by1895, India had started its own locomotives and in 1896 sends engineers and locomotives to help build the Uganda railway.

Soon various independent kingdoms built their own rail system and the network spread to the region that becomes the modern day states of Assam, Rajasthan and Andhra Pradesh. A railway board operated under aegis of the department of commerce and industry and had time in its history; the railways began to make a tidy profit.


**Figure 1.1:** The kharagpur Workshop:1st Indian loco-Workshop

### 1.1.2 Government Initiatives

Few recent initiatives taken up by the Government are:

1. As of December 2018, the Government of India is considering a High Speed Rail Corridor project between Mumbai and Nagpur.

2. As of November 2018, Indian Railways is planning to come out with a new export policy for railways.

3. The Government of India is going to come up with a 'National Rail Plan' which will enable the country to integrate its rail network with other modes of transport and develop a multi-modal transportation network.

4. A 'New Online Vendor Registration System' has been launched by the Research Designs & Standards Organization (RDSO), which is the research arm of Indian Railways, in order to have digital and transparent systems and procedures.

5. The Government of India has signed an agreement with the Government of Japan under which Japan will help India in the implementation of the Mumbai-Ahmadabad high speed rail corridor along with a financial assistance that would cover 81 per cent of the total project cost.

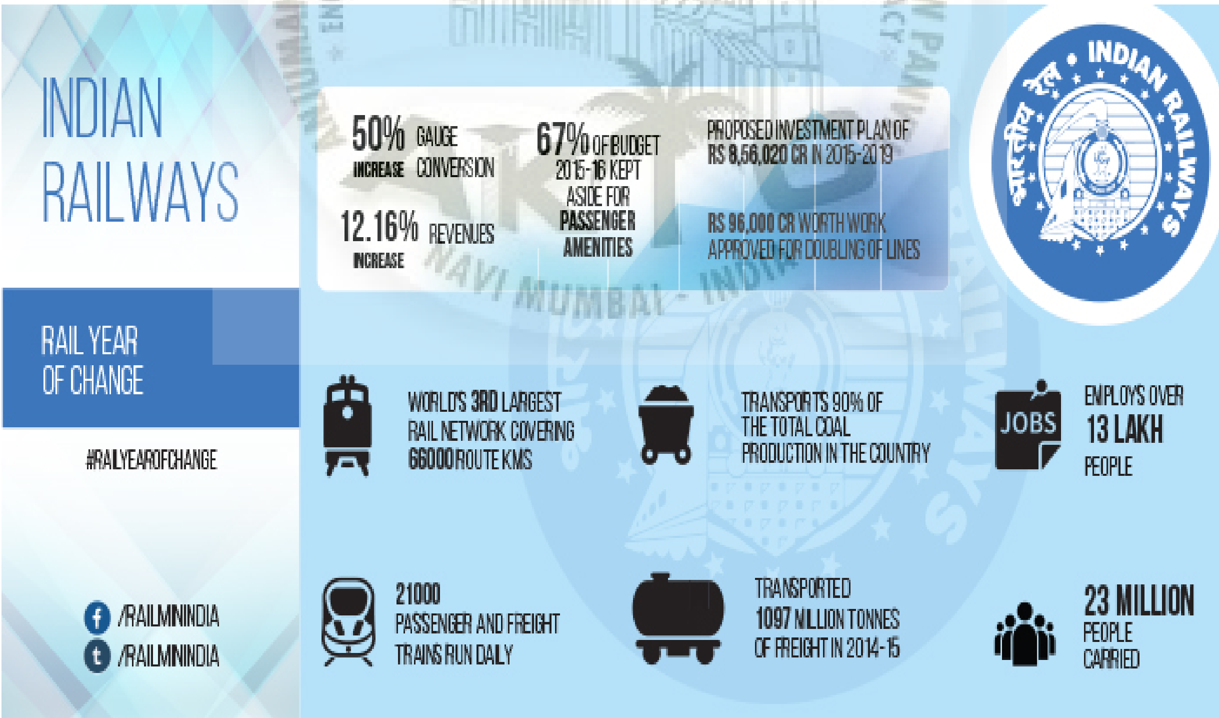



**Figure 1.2:** Indian Railway current year plan

### 1.1.3 Zonal Details

| | Name | Abbr. | Headquarters | Divisions |
|---|---|---|---|---|
| 1 | Central Railway | CR | Mumbai | Bhusawal,Nagpur, Mumbai(CST),Solapur, Pune |
| 2 | Eastern Railway | ER | Kolkata | Malda, Howrah, Sealdah, Asansol |
| 3 | East Central Railway | ECR | Hajipur | Danapur,Dhanbad, Sonepur, Mughalasarai, Samastipur |
| 4 | East Coast Railway | ECOR | Bhubaneswar | Khurda road, Waltair, Sambalpur |
| 5 | Northern Railway | NR | Delhi | Ambala,Ferozpur, Lucknow, Moradabad, New Delhi |
| 6 | North Central railway | NCR | Allahabad | Allahabad,Jhansi, Agra |
| 7 | North Western Railway | NWR | Jaipur | Bikaner,Jodhpur, Jaipur, Ajmer |
| 8 | North Eastern Railway | NER | Gorakhpur | Lucknow,Varanasi, Izatnagar |
| 9 | Northeast Frontier Railway | NFR | Maligaon (Guwahati) | Katihar,Lumding, Tinsukhia, Alipurduar, Rangiya |
| 10 | Southern Railway | SR | Chennai | Chennai, Madurai, Palghat |
| 11 | South Central Railway | SCR | Secunderabad | Secunderabad, Hyderabad, Guntakal, Vijayawada-Guntur, Nanded |
| 12 | South Eastern Railway | SER | Kolkata | Kharagpur, Chakradharpur,Adra, Ranchi |
| 13 | South East Central Railway | SECR | Bilaspur | Nagpur, Bilaspur, Raipur |
| 14 | South Western Railway | SWR | Hubli | Bangalore, Mysore, Hubli |
| 15 | Western Railway | WR | Mumbai | Bhavnagar, Mumbai Central, Ratlam, Rajkot, Vadodara,Ahemadabad |
| 16 | West Central Railways | WCR | Jabalpur | Jabalpur, Bhopal, Kota. |
| 17 | Metro Railway | MTP | Kolkata | |
| 18 | Konkan Railway | KR | Navi Mumbai | |

**Table 1.2:** Zonal Details

## 1.2 About Matunga Railway Workshop

### 1.2.1 Introduction Matunga Railway Workshop

The Carriage Workshop, Matunga was set up in 1915 as a repair workshop for broad gauge and narrow gauge coaches and wagons of the erstwhile Great Indian Peninsular(GIP) Railway.The workshop covers a triangular piece of land/area of 35 hectares, including a covered area of about 11 hectares, skirted by the Central Railway suburban corridors on the east and the Western Railway corridors on the west.

The workshop now carries out Periodical Overhaul (POH) and heavy corrosion repairs of main line as well as EMU coaches.

The workshop is certified with ISO 9001/2000 and ISO 14001/1996 since 2001 & 2002 respectively. It was last re-certified for ISO 9001-2000 in 2007 & ISO 1400-2004 in 2008. Now this workshop is going one step ahead to adopt Integrated Management System covering ISO: 9000, ISO: 14000 & ISO: 18000 (Occupational Health and Safety Assessment Series). The system is likely to be implemented by July 2011.

The Workshop Obtained the Integrated Management System(ISM) in the year 2015. The Workshop was also certified with ISO 5000:2011 ,ISO 3834-2:2005,along with GreenCo Bronze Rating - in the year 2017. In the year 2018, it got ISO/IEC/7025:2005 & 5S approved.

**Figure 1.3:** Central Railway/Indian Railway

**Figure 1.4:** Matunga Workshop-HCR shop

### 1.2.2 Main activities for the year 2018-19

| ACTIVITIES | RECIEVED (Per year) | OUT-TURN (Per year) |
|---|---|---|
| POH of Mail/Express/-Passenger Coaches | 1592 Coaches & 399 AC coaches | 1678 Coaches & 404 AC coaches |
| POH of EMU Coaches | 897 Coaches & 136 Coaches from SANPADA | 897 Coaches & 148 Coaches from SANPADA |
| Total No. of Coaches | 3006 Coaches | 3127 Coaches |

**Table 1.3:** Main Activities for the year 2018-19

### 1.2.3 A Few Firsts of Matunga Workshop

1. RETRO FITMENT OF FLOORING IN LAVATORIES OF PASSENGER COACHES WITH NON-TOXIC IN-SITU FLOOR.
   In order to improve cleanliness and hygiene of the toilets in coaches. Epoxy flooring is being provided. Matunga is the First Zonal Workshop on Indian Railways to start Epoxy Flooring in Toilets on a programmed basis since Sept'2010.

2. FIRST ZONAL WORKSHOP ON INDIAN RAILWAYS TO START CUSHIONING IN UNRESERVED COACHES FROM OCT. 2008.
   Provision of cushioned seats in all GS/SLR coaches during POH has been carried out.

3. FIRST ZONAL WORKSHOP ON INDIAN RAILWAYS TO PROVIDE ALL COACHES WITH BOGIE MOUNTED AIR BRAKE SYSTEM BY THE END OF JAN.2011.
   The bogie mounted brake system is not only more reliable but also gives faster braking and release of brakes thus making trains faster.

4. FIRST WORKSHOP TO IMPLEMENT PAYMENT TO CONTRACTORS & SUPPLIERS THROUGH NEFT FROM 15TH JULY 2010.

5. FIRST ZONAL WORKSHOP ON INDIAN RAILWAYS TO START CLEANING OF BOGIES BY GRIT BLASTING IN 2004.
   This has improved the safety standards of Rolling stock by enabling better examination.

6. FIRST ZONAL WORKSHOP IN INDIAN RAILWAYS TO PROVIDE CONSULTANCY FOR ISO 9001:2000 CERTIFICATE TO ANOTHER UNIT. (Kalyan Freight Depot in the year 2003)

7. FIRST RAILWAY UNIT in which more than 3500 WORKERS, SUPERVISORS, UNION OFFICIALS AND OFFICERS took pledge on the New Year day against PASTING OF POSTERS on walls on 1st January, 2003.

8. FIRST ZONAL RAILWAY WORKSHOP TO CONVERT ALL ARMES AND 'A' CLASS ARTS INTO AIR BRAKE IN THE YEAR 2002.

9. FIRST RAILWAY COACHING WORKSHOP IN INDIAN RAILWAYS TO CONVERT 100% OF MAIL/EXPRESS RAKES INTO AIR BRAKE IN THE YEAR 2002.

10. FIRST ZONAL RAILWAY WORKSHOP IN INDIAN RAILWAYS TO GET ISO-14001 CERTIFICATION IN THE YEAR 2002.

### 1.2.4 Notable Accomplishments

- Coaches For Heritage Special
- Lifeline Express
- Deccan Odyssey.
- Retro-fitment Of Dc To Ac/Dc EMU(Seimens).
- Coaches for Utkrash Express.

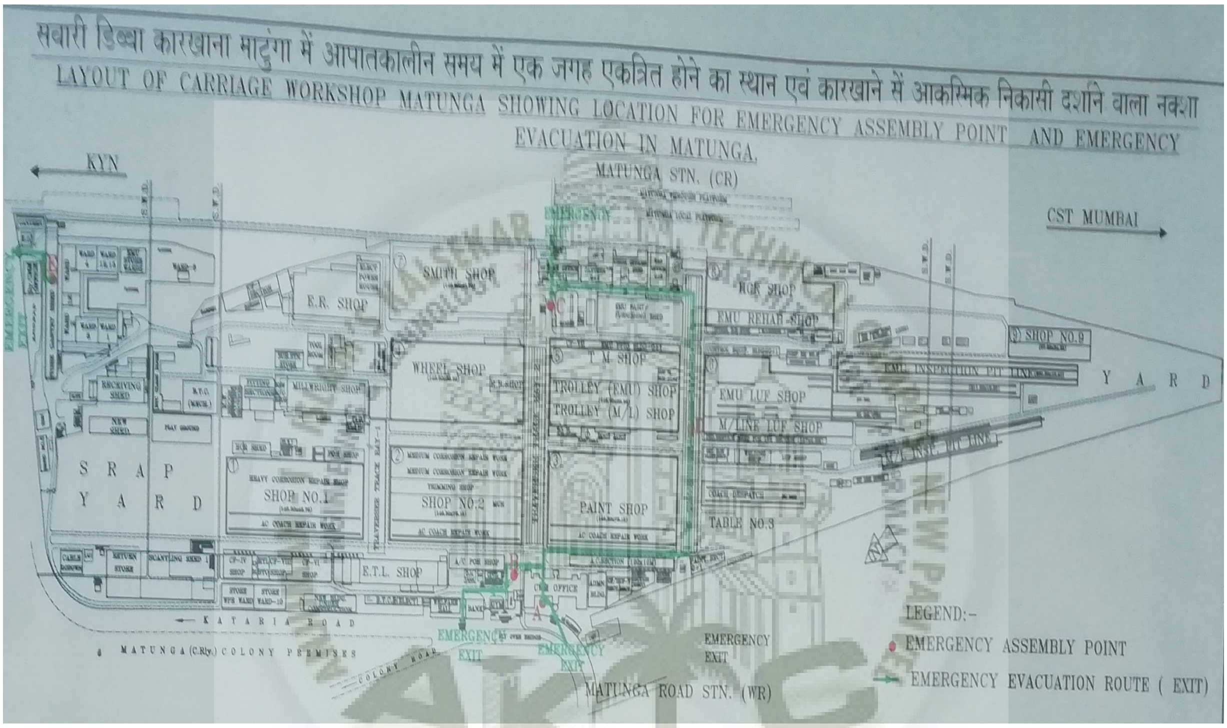



**Figure 1.5:** Matunga Workshop-Plant Layout

### 1.2.5 Innovations by Matunga Workshop

- Head-stock Manipulator and Fixture.
- Gravity Conveyor System.
- Motorized Bearing and Axle Box Extraction System.
- Roof Leakage Testing by sprinkling water on the Roof.
- BSS/Brake Block Hanger Testing and Painting Integrated Workstations.
- Provision of Venturi type Ventilators and Relocating body side windows of kitchen area.
- Provisions of Model Room for ERRU training.

- Commissioning Variable Voltage Variable Frequency Drive on alternator testing beds.
- Regular Training of Matunga Staff at Basic Training Center.

## 1.3 Processes Involved in Carriage Repair Workshop

1. RECEIVING THE COACH FROM YARD:
   The coach to be repaired is received from the yard. 1 car means 8 coaches.
2. SHUNTING OF COACH:
   Each coach to be separated into two parts:
   (a) Shell
   (b) Trolley
3. PRE-INSPECTION AND CLEANING UNDER FRAME AS WELL AS WATER TANK ATTENTION:
   Parts to be repaired and the under frame along with water tank are also cleaned.
4. UNLOADING OF MECHANICAL AND ELECTRICAL COMPONENT:
   All the components which function on electrical and mechanical energy are unloaded.
   e.g.: Fans, seat, trolley, battery, doors, etc. These components are removed in order to reduce the weight of coach as well as for their repair and maintenance work.
5. LIFTING OF COACH:
   The coach is lifted at a higher position by using a lifting crane and is separated from trolley.
6. TROLLEY WILL BE SENT TO TROLLEY SHOP:
   The parts of the trolley are further sub-divider into 2 sections:
   (a) Wheel to and fro wheel shop: Here the wheel is repaired by first checking its diameter which should not be less than 830mm.
   (b) Springs to and fro smithy shop: Here the springs are inspected having any cracks, abrasion, and corrosion. If the cracks are invisible to naked eye then bosh cleaning tank is used. It there are any cracks in the spring then the spring is thrown away and a new spring is used.
7. TR/ML (TROLLEY/MAIN LINE) REPAIR SHOP:
   All the other bogey components are sent to this shop for repairing.

8. A NEWLY REPAIRED BOGEY IS OBTAINED

9. LOWERING THE COACH:
   Here all the repaired parts of the coach are assembled together and the coach is lowered and assembled with the bogey.

10. PAINTING:
    Layers of various paints are applied to the coach. Anti-corrosive paints are used. This process requires 9 days.

11. INTERIOR FURNISHING:
    This step includes furnishing of interior coach which includes seats, walk through etc.

12. LOADING AND UNLOADING OF MECHANICAL COMPONENTS:
    In this step all the electrical and mechanical components which were unloaded earlier are loaded back to their original place after their testing and maintenance.

13. AIR BRAKE TESTING:
    Air brake testing is done which is the most important part of this POH. It is a 1-day process. Twin pipe graduated air brake system is used.

14. FINAL INSPECTION BY NTEX (NEUTRAL TRAIN EXAMINER):
    The organizing committee is NCO (Neutral Control Organizing). NTEX will always do the final inspection of the newly obtained coach.

15. DISPATCH TO TRAFFIC:
    After its final inspection the train is dispatch for its use.

# Chapter 2

# INTRODUCTION

## 2.1 Introduction to ICF Trolley:

ICF Bogie is a conventional railway bogie used on the majority of Indian Railway main line passenger coaches. The design of the bogie was developed by ICF (Integral Coach Factory), Perambur, Chennai, India in collaboration with the Swiss Car & Elevator Manufacturing Co.,Schlieren, Switzerland in the 1950s. The design is also called the Schlieren design based on the location of the Swiss company.

The bogie can be divided into various subsections for easy understanding as follows:

| | | |
|---|---|---|
| a. Bogie Frame | b. Bogie Bolster | c. Centre pivot pin |
| d. Wheel set assembly | e. Roller bearing assembly | f. Brake beam assembly |
| g. Brake levers | h. Brake cylinder | i. Secondary Suspension |
| j. Primary Suspension | k. Brake blocks | l. Brake head |

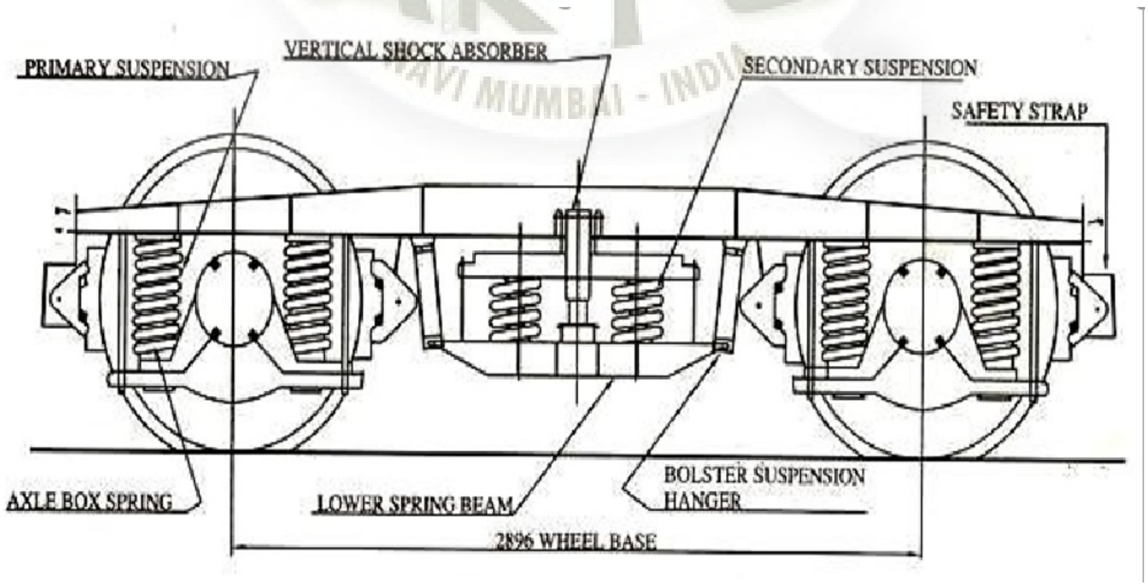



**Figure 2.1:** ICF Trolley

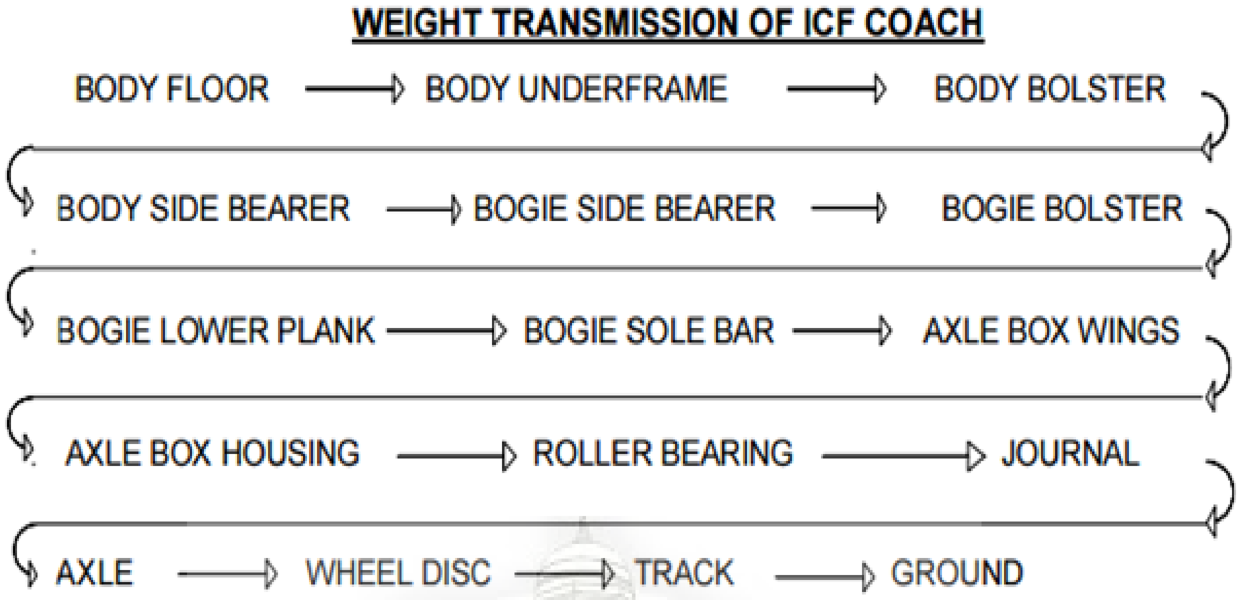



**Figure 2.2:** Weight Transmission of ICF Coaches

The Weight Transmission of ICF Coaches is shown in the above Figure 2.2. As seen the weight of the whole bogie is 1st transmitted through the Bolster Springs.

Indian Railways plays a key role in transportation of goods and passengers across India. As part of our contribution we have taken up a project related to Indian Railways. Indian Railway has vast maintenance regarding to coaches. Every coach after working for 18 months comes for POH. This project will involve creating a solid model of the helical spring using Autodesk Inventor software with the given Specifications and analyzing the same model by using ANSYS 19.1 software, under transverse loading. Behavior of the spring is observed for particular loading. Particular 13T coaches have been selected for analysis.

Each Coach has two bogies with 2 axles each. A bogie with 2 axles is shown in fig:2.1. Suspension of bogie consists of primary and secondary suspension system. Springs used for primary suspension is known as axle box spring while for secondary is known as bolster spring.Total 16 axle box spring and 8 bolster springs are used. Suspension is provided in Coach body for:
1) Better riding comfort
2) Improved reliability and reduced maintenance
3) Capacity to sustain super dense crush load .

Most common cause of spring failure is the fatigue fracture, which is due to imperfections present in the material or due to crack formation during service.

**Figure 2.3:** The daily intake of Springs

## 2.2 Observations:

The maintenance record at Matunga Workshop indicates that there is very high rate of failure of Secondary spring. For instance in 2007-18 the Secondary spring was replaced on 30 instances as against 8 instances of axle primary spring. Following are the observations on failed spring:

i) The spring usually breaks between first to third coils.
ii) Failure initiates at the inner radii of spring which progresses and shears the spring into two pieces.
iii) The scratches on the damper confirm the deformation of assembly by about 25mm more than the stationary condition indicating higher loads while running.

(**a**) Failure Seen

(**b**) Most Common Failure Position

**Figure 2.4:** Failure Observed In BOLSTER Springs

## 2.3 Problem Definition:

Through excessive testing of various bolster spring using Magna-Flux technique, it was found that the number of cracks have increased a considerable amount. The reason for increase in cracks and failure of springs could be as follows:

• Increase in overall weight of the coaches due to introduction of BIO-TOILETS.
• Increase in gross weight of the coaches in general bogies due to over-crowding /over-loading of goods more than the designed load.
• Impact loading on springs due to uneven railroads.
• Uneven distribution of load.

In the passenger trains, the no of passengers entering (Super Dense Crush Load) into the coach cannot be controlled and hence the payload of the coaches increases from 13 tons to 19 tons. This abnormal increase of payload reduces the riding clearance between the coaches and wayside platforms and also reduces the buffer height resulting in severe hitting of the coach on the platform.

Due to the Super Dense Crush Load the bolster springs become solid, which in-turn damages/breaks the coil spring resulting in discomfort to the passenger.

## 2.4 Process Layout Of Smithy Shop:

| Sr.no | ACTIVITY | CHARACTERISTICS TO BE MONITORED | RESOURCES REQUIRED |
|---|---|---|---|
| 1 | Receiving of Released coils | Verification of Quality | Visual |
| 2 | Inspection | Cracked/Broken Spring | Visual |
| 3 | Cleaning with wire brush | Surface cleaning | Wire brush |
| 4 | Shot peening | Surface cleaning | Shot peening machine |
| 5 | Load testing of coil | As per Annexure I & II of SMWI 13 | Load testing machine |
| 6 | Visual inspection with magnifying glass | Cracks and dent marks | Visual,magnifying glass |
| 7 | Tagging for color codes | Category of spring | Metallic tags, wire |
| 8 | Magna Flux testing | cracks | Magna flux testing machine |
| 9 | Paint red oxide | Tagging of spring | Red oxide paint |
| 10 | Paint Black Enamel | Painted surface of spring | Black Enamel paint |
| 11 | Color coding | Tag as per category of spring | Brush, green, blue, yellow paints |
| 12 | Stacking for dispatching | Color coding of spring | Manual |

**Table 2.1:** Process Layout Of Smithy Shop

# Chapter 3

# LITERATURE REVIEW

M. Sudhakar Reddy, (2013) Criticized that the Springs used in railway coaches have been failing prematurely much before their intended service life. The springs are made with quality materials. Before being put to service, the springs are tested with extensive Non-Destructive Testing Methods which are approved by ISO standards to make sure that quality parts are used. However, the springs still fail before their service life ends.
To study the dynamic behavior of the springs, 3D solid model of helical springs were modeled with PRO/E. Static and Dynamic stress analysis were carried out using ANSYS to understand the Structural and Dynamic response of the springs. Spring behavior was observed under prescribed or expected loads. Based on the results design modifications were suggested for better life without failure in service.

B. Praveen Kumar,(2014) Criticized that On account of the stresses locomotives coil springs have been undergone the failure prematurely before its service life. The present work is investigation on to reduce the premature failure and improve the service life of helical compression spring. The life of spring is improved by optimum design and analysis by variation of wire diameter. Results indicate the von-moiss stresses are decreased for increased values of wire diameter of coil spring.
He finally concluded that spring strength effected by varying diameter of spring coil and at maximum diameter spring is expected to loss the elastic property and unsuitable for the service.

K Pavan Kumar,(2013) worked on attempts to analyze the safe load of the locomotive suspension spring with different materials. A typical locomotive suspension spring configuration is chosen for study. In this present work is carried out on modelling and analysis of primary suspension spring (60Si2MnA) is to replace the earlier conventional steel helical spring (Chrome Vanadium). The work is to reduce the overall stress and deflections of the helical spring by using the new materials.
From the above analysis, he concluded that even though the stresses are almost equal, but the deflection of suspension spring is less when comparative to the Chrome Vanadium and it will works efficiently with less maintenance.

Rohan Joshi, (2015) Criticized that Visual examination shows failure that is common between first to third coils. However, the exact time of failure cannot be determined as the coaches come for POH after 18 months. Some cracks also negotiate during load testing. Pattern of cracks showing it may subject to transverse forces. The cracks are detected in Magna-flux testing. The present works attempt to analyze design of primary suspension springs used in Railway coaches under transverse loading while negotiating curved path by using ANSYS 14.5 software. Stresses induced are compared with allowable stresses. Typical 16T coaches have been considered for the failure analysis.
He concluded that spring is enough sufficient to withstand the loads on straight path. However While travelling on the curved path the shear stress are nearer to allowable stress.. Based on the results, he also concluded that to negotiate curved path a lateral damper must be used for absorbing lateral loads. For improvement of spring life it will be always better to use a damper rather than to spend money on the maintenance and replacement of spring.

Gupta Manav,(2015) Studied dynamic response of railway coach, which is a key aspect in the design of coach. Improving the dynamic behaviour focus on optimization of primary passive suspension of coach. The paper provides a comparative analysis of different research conducted on primary suspension of railway coaches.

# Chapter 4

# DESIGN

## 4.1 Spring Details (FOR 13T NON-A/C COACHES)

### 4.1.1 Spring Space:

Wire Diameter = 42mm
Outer Diameter = 302mm
Mean Diameter = 260mm
No. of coils = 5.75
Free Height = 385mm

### 4.1.2 Material Data:

Type of steel = Chromium Vanadium Steel-52Cr4Mo2V
Built to BIS IS:3195 specifications.
Young's Modulus = 2.07E+11 Pa
Density = 7860 kg/m3
Stress Concentration factor "k" = 1.264
Modulus of rigidity G = 79300 MPa

### 4.1.3 Loads:

1.A load of 33 KN is applied on top of the spring for standard design stress calculation.
2.Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 4.1.4 Boundary Conditions:

The bottom of the spring needs to be fixed i.e. fixed supports.

## 4.2 Analytical Calculations of Bolster Spring Calculation Part: (Existing System)

### 4.2.1 Allowable Stress:

Assuming,Average service
no. of cycles $\geq 10^4 \leq 10^6$

$$[\tau_d] = .324 \times \sigma_u$$

$$[\tau_d] = .324 \times \frac{1735}{d \cdot 1}$$

$$[\tau_d] = .324 \times \frac{1735}{42 \cdot 1}$$

$$[\tau_d] = 386.829 N/mm^2$$

### 4.2.2 Spring Under Design Load:

$Load = P = 33000N$
$d = 42mm$
$D = 260mm$
spring constant:
$c = D/d = 260/42 = 6.19$

Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$

$$q = \frac{79300 \times 42^4}{8 \times 260^3 \times 5.75}$$

$$q = 305.205 N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$

$$y_{max} = \frac{8 \times 33000 \times 260^3 \times 5.75}{79300 \times 42^4}$$

$$y_{max} = 108.12mm$$

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

Wahl's stress factor:

$$k_s = \frac{4 \times c - 1}{4 \times c - 4} + \frac{.615}{c}$$
$$k_s = 1.24386$$

$$\tau_{ind} = 1.24386 \times \frac{8 \times 33000 \times 6.19}{\pi \times 42^2}$$
$$\tau_{ind} = 366.79 N/mm^2$$

As,

$$\tau_{ind} = 366.79 N/mm^2 < [\tau_d] = 386.829 N/mm^2$$

Design is SAFE.

But,there has been a significant increase in load of the coaches due to BIO-TOILETS & Increase in passengers.
Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 4.2.3 Spring Under Present(Increased) Load:

$Load = P = 41000N$
Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$
$$q = \frac{79300 \times 42^4}{8 \times 260^3 \times 5.75}$$
$$q = 305.205 N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$
$$y_{max} = \frac{8 \times 41000 \times 260^3 \times 5.75}{79300 \times 42^4}$$
$$y_{max} = 134.336 mm$$

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

$$\tau_{ind} = 1.24386 \times \frac{8 \times 41000 \times 6.19}{\pi \times 42^2}$$

$$\tau_{ind} = 455.744N/mm^2$$

As,

$$\tau_{ind} = 455.744N/mm^2 > [\tau_d] = 386.829N/mm^2$$

Design is UN-SAFE.

## 4.3 Software's Used:

Two software's were used to carry out this study.
1.Modelling Software-Autodesk Inventor.
2.Analysis Software-ANSYS 19.1(Student Version).

### 4.3.1 Modelling Software(Autodesk Inventor):

**Autodesk Inventor:**

Autodesk Inventor is a 3D mechanical solid modeling design software developed by Autodesk to create 3D digital prototypes. It provides 3 years free license for students, hence it proves to be a great platform for students to explore, learn & create different ideas.

Autodesk Inventor allows 2D and 3D data integration in a single environment Inventor includes powerful parametric, direct edit and free form modeling tools as well as multi-CAD translation capabilities and in their standard DWG drawings.

Its allows easy feature to design springs. It has a feature called "Coils" for making springs easily with many operation which can be performed in it. Example:Output type, parameters such as pitch,height revolution,taper,coil ends,etc.

**Steps to Model springs in Inventor:**

1. Open new project→ select Standard(mm).ipt → click create.
2. Go to Start 2D sketch → select a plane to work on (ex:X-Y plane).
3. Sketch a profile the represents the cross-section of the coil feature (use 'circle ◯' command to create circle). Then, use the Line command or Work Axis

command to create an axis of revolution for the coil.

4. Go to Dimensions and add dimensions to the figure → Click on Finish Sketch.

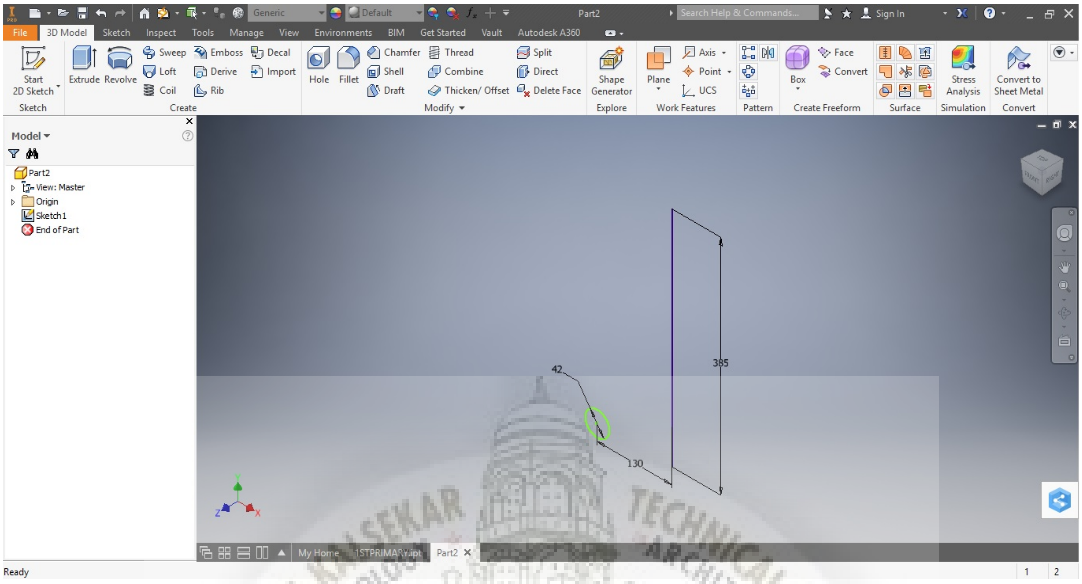



**Figure 4.1:** Creating Geometry in Inventor

5. Click 3D Model tab→ Coil.

6. In the Coil Shape tab of the Coil dialog box, click Profile and then select the profile. → Click the axis of revolution. It can be at any orientation but cannot intersect the profile. → Choose a Rotation direction: clockwise or counter-clockwise.

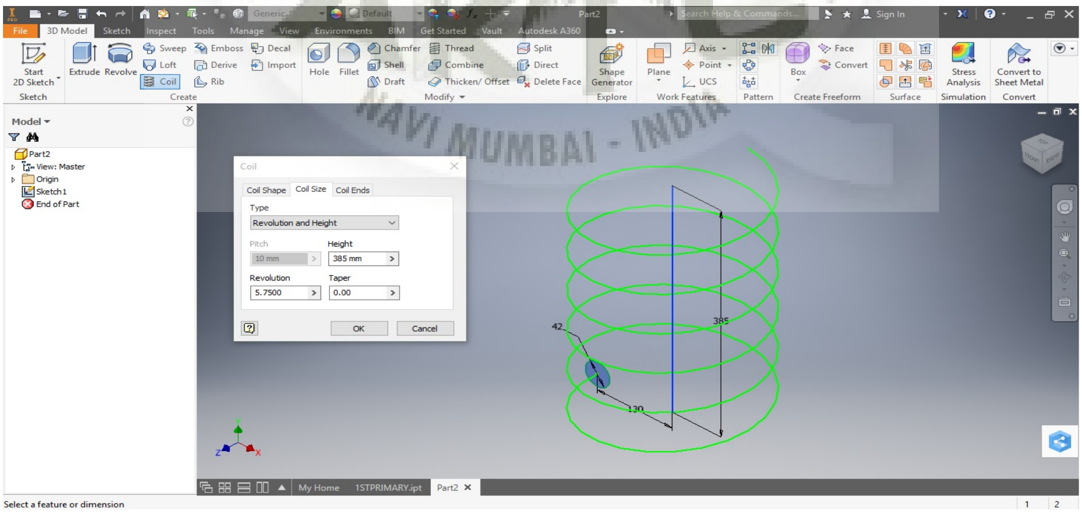



**Figure 4.2:** Modelling coil(spring) in Inventor

7. Click on coil size → type → revolution and height → add the values of no.of revolutions & height. → Click on coil ends → select flat ends for both start and end → click OK.

8. Select one end of the coil in order to make profile for making square & ground ends → create sketch on the coil profile.

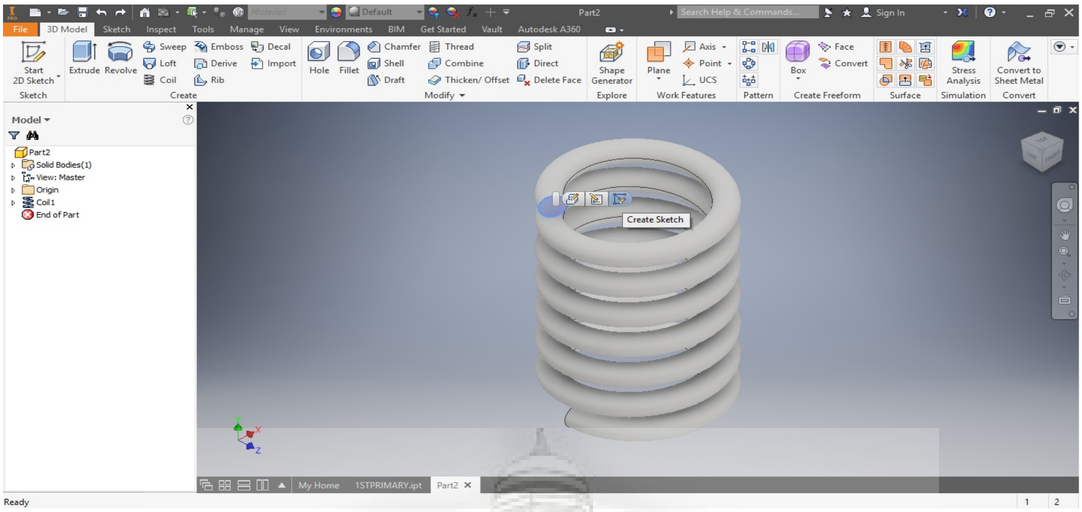


**Figure 4.3:** Modelling coil(spring) with Square & ground ends in Inventor

9. Select rectangle command from task bar → create a rectangular profile from the center of the coil as seen in the figure 4.4 → Click on finish sketch.

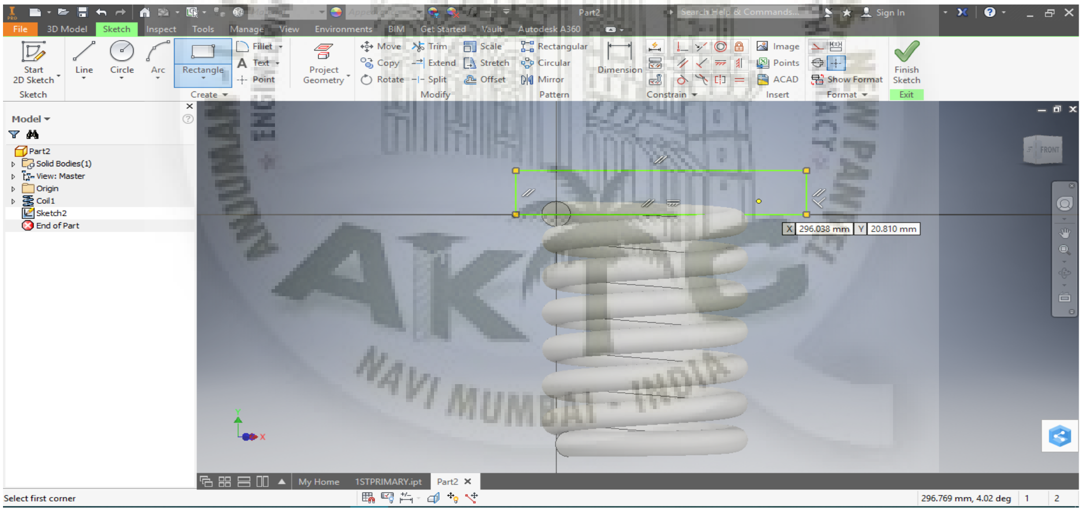


**Figure 4.4:** Modelling rectangle geometry for square & ground ends in Inventor

10. Go to 3D model → Select extrude command → select profile(rectangular profile made in earlier step) → select cut extrude → select symmetric cutting → select distance to be extruded → Click OK.

11. Repeat Steps 8 to 10 ,while selecting other end of the coil.

12. Convert the file into IGES/STEP file by clicking files → export → cad format → save type IGES/STEP files.

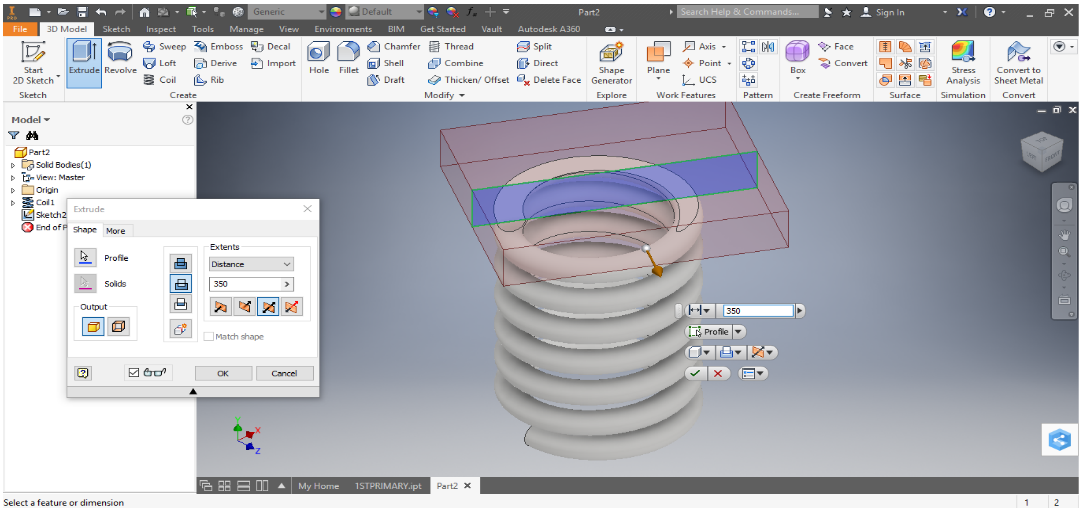


**Figure 4.5:** Cut Extruding rectangle geometry for square & ground ends in Inventor

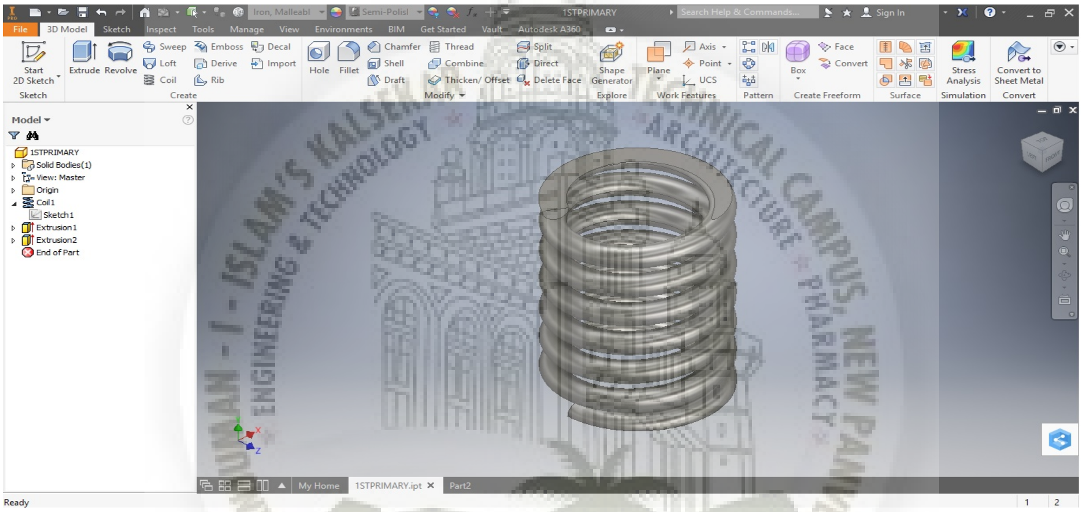


**Figure 4.6:** Modelled Spring in Inventor

### 4.3.2 Analysis Software(Analysis Software-ANSYS 19.1):

**Analysis Software-ANSYS 19.1:**

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests.

Ansys Student version is an initiative by the company to provide free access to their software for students to work on homework, capstone projects, student competitions and more.

Most Ansys simulations are performed using the Ansys Workbench software, which

is one of the company's main products. Typically Ansys users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.
Thus, Ansys is the most Commonly used analysis & simulation software.

**Steps involved in analysis of springs using ANSYS 19.1:**

1. Create Analysis
   From the Toolbox, drag a Static Structural or Static Structural (Samcef) template to the create standalone system.

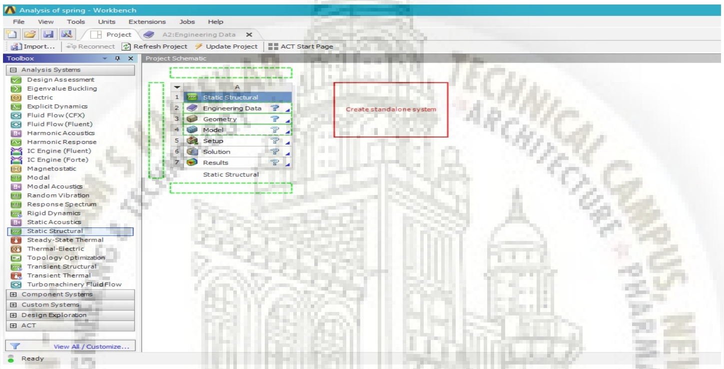


**Figure 4.7:** creation of system in Ansys

2. Define Engineering Data
   To manage materials, right-click on the Engineering Data cell in the analysis system schematic and choose Edit.
   Click on click to add new material → Add name of material → select required properties from the toolbar on the left → add density,isotropic elasticity, etc. according to amount of data been given.

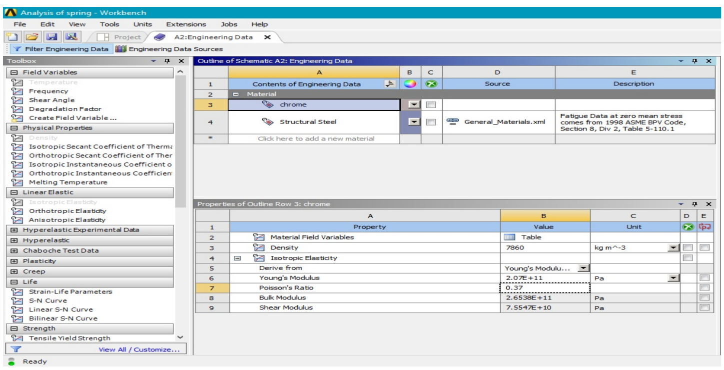


**Figure 4.8:** Adding of engineering add into Ansys

3. Add Geometry
   Go to project → right click on geometry → import geometry → browse.
   Select the IGES/STEP file of the model that was created using modelling software.

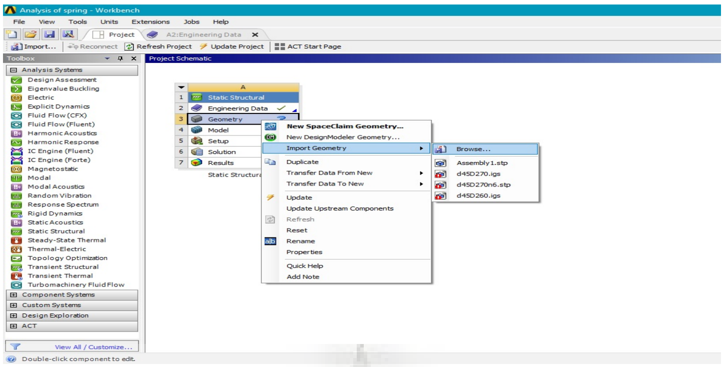
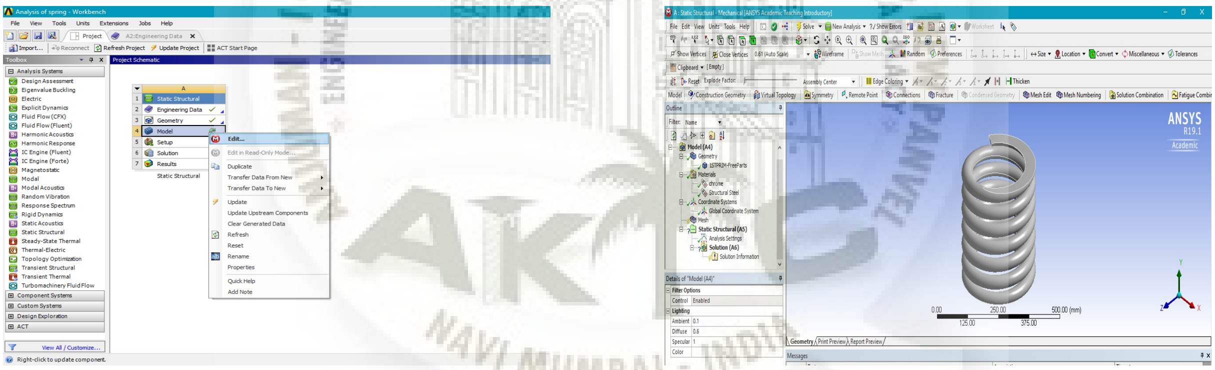


**Figure 4.9:** Adding/importing Geometry in Ansys

4. Define Part Behavior
   Right-click on the Model cell in the analysis system schematic → choose Edit
   The Mechanical application opens with the environment representing the analysis system displayed under the Model object in the tree.



**(a)** Opening Modelling cell **(b)** Mechanical App. in Ansys

**Figure 4.10:** Modelling using Ansys mechanical

5. Mechanical application will open → go to material assignment → select material as chrome .

6. Ansys has default setting of global positioning system.

7. Apply Mesh Controls/Preview Mesh
   Go to Mesh → generate mesh.
   Due to the software being students version there are some restrictions as to the no. of nodes/elements which is limited to 32000.Thus ,we can not use fine mesh ,only coarse mesh can be used.Use standard Analysis Settings.

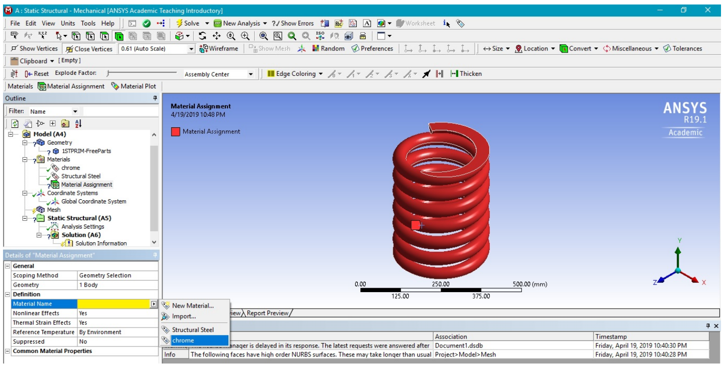
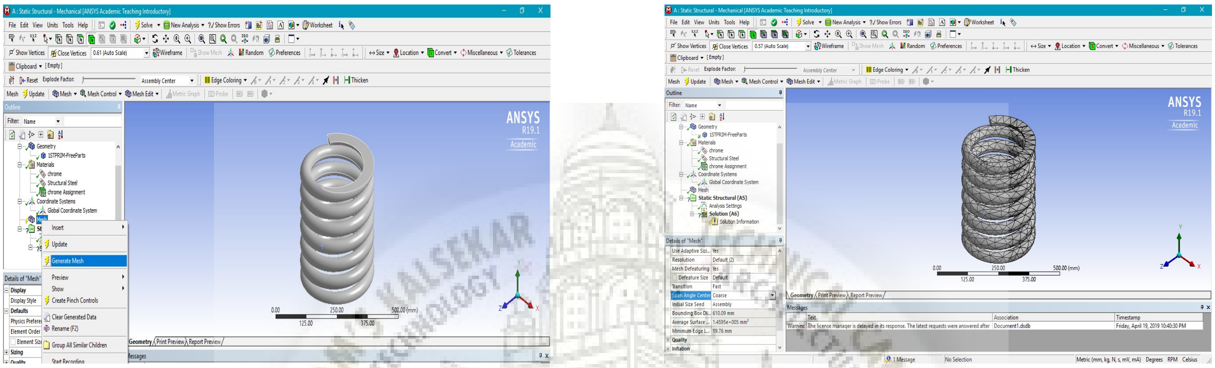


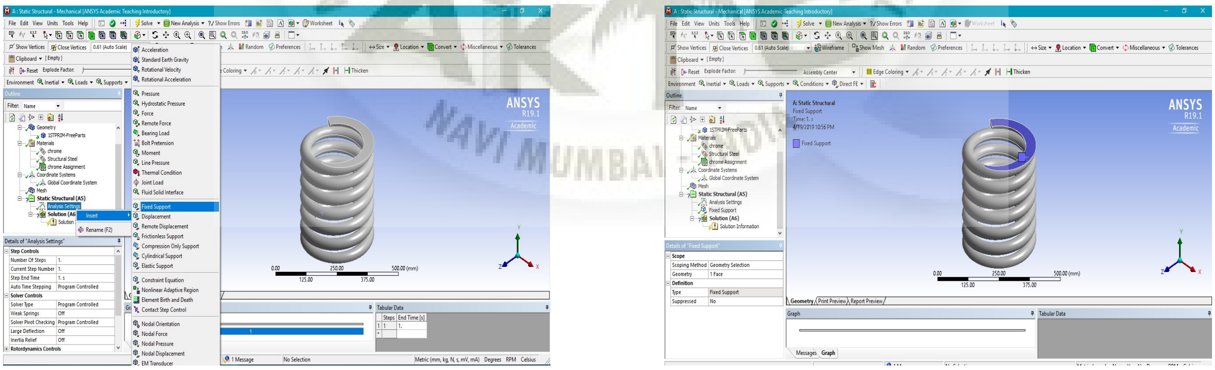
**Figure 4.11:** Material assignment



**(a)** Meshing Tool **(b)** Generated mesh

**Figure 4.12:** Meshing in Ansys

8. Apply Fixed Support.
   Click on analysis setting → insert → fixed support → select the face to fix → click apply.

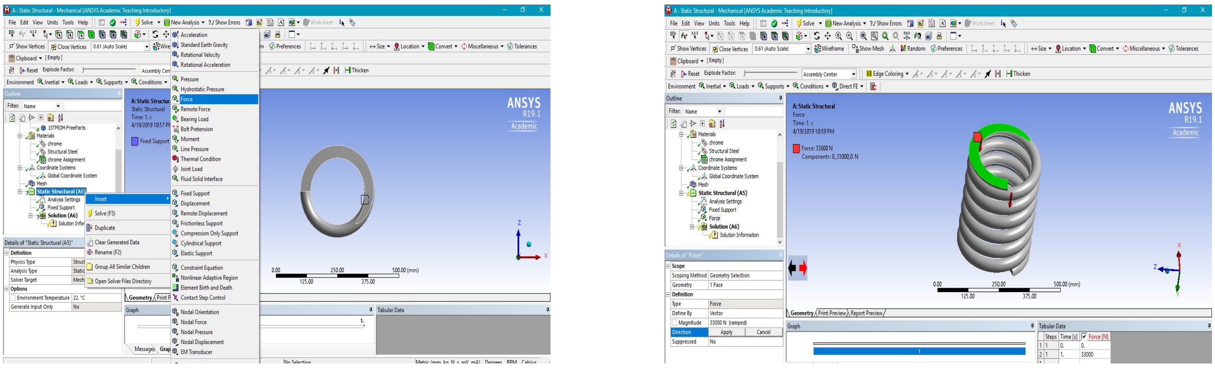


**(a)** Tool to apply fix support **(b)** Object after applying fixed support

**Figure 4.13:** Applying fixed support in Ansys

9. Apply Forces.(on the opposite end of the spring)
   Click on analysis setting → insert → force → select the face on which force is to be applied → add magnitude → click to change direction of force.

10. Insert solver for deformation
    click on solution → insert → deformation → total.



**(a)** Tool to apply force **(b)** Object after application of Force

**Figure 4.14:** Applying force in Ansys

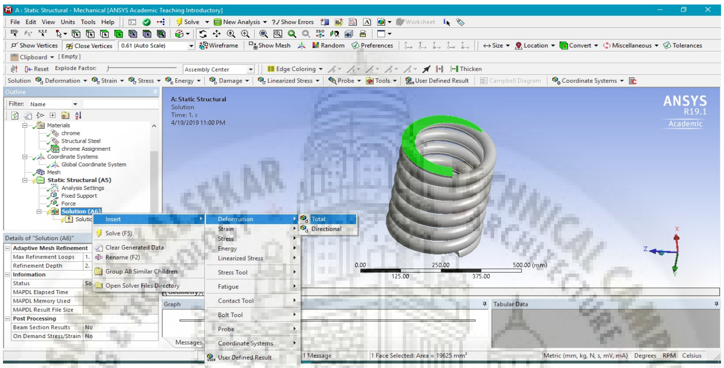


**Figure 4.15:** Applying Solver for deformation

11. Insert solver for stress
    click on solution → insert → stress → equivalent(von-moises)

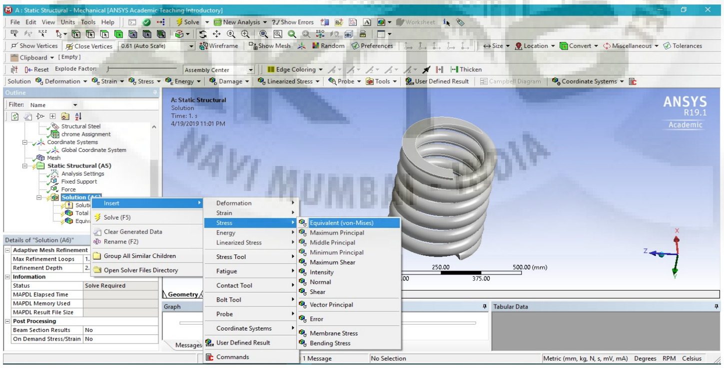


**Figure 4.16:** Applying Solver for stress

12. Click on Solve.

13. Check for solution/results:
    click on deformation/stress in solutions & it will show the results for deformation & stress.

## 4.4 Analysis of Bolster Spring Using ANSYS 19.1: (Existing System)

### 4.4.1 Spring Under Designed Load of 33000 N:

**Total Deformation:**

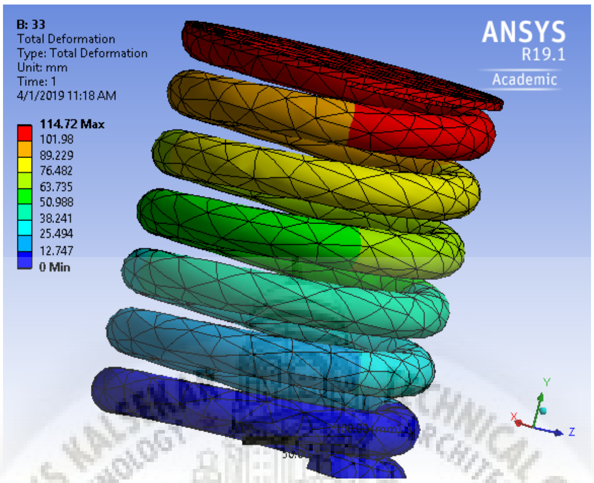



**Figure 4.17:** Total Deformation for 33 KN

Total Deformation=114.72 mm

**Equivalent Stress(Von-Moises):**

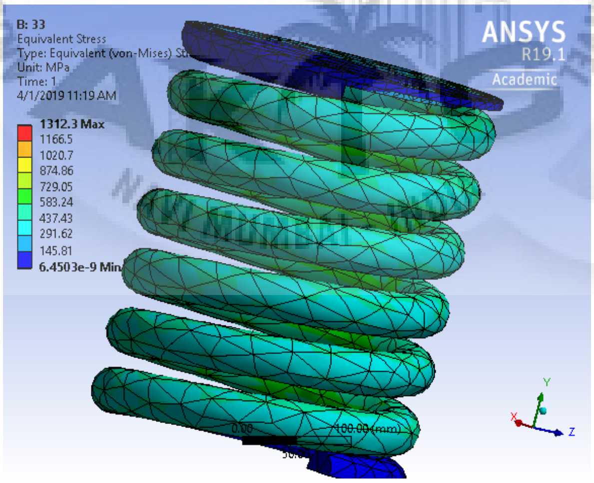



**Figure 4.18:** Equivalent Stress(Von-Moises) for 33 KN

Equivalent Stress(Von-Moises)=285.24 $N/mm^2$

### 4.4.2 Spring Under Present(Increased) Load of 41000 N:

**Total Deformation:**

Total Deformation=142.53 mm

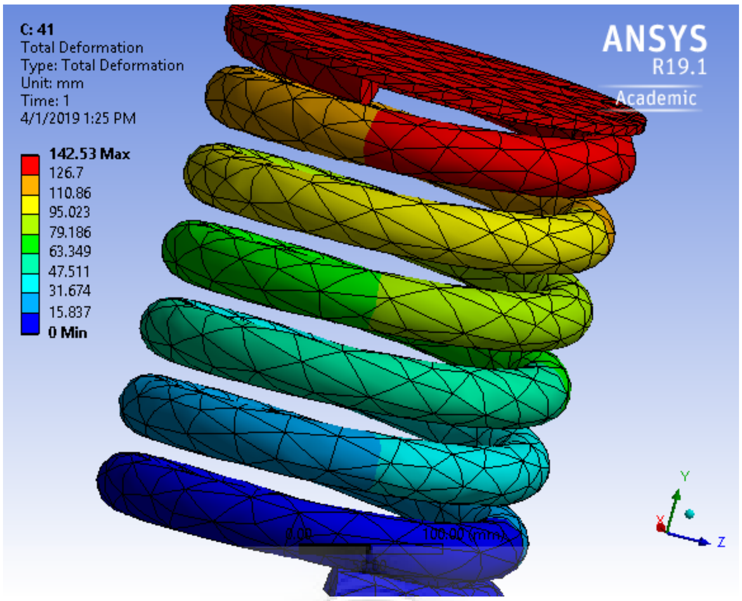



**Figure 4.19:** Total Deformation for 41 KN

**Equivalent Stress(Von-Moises):**

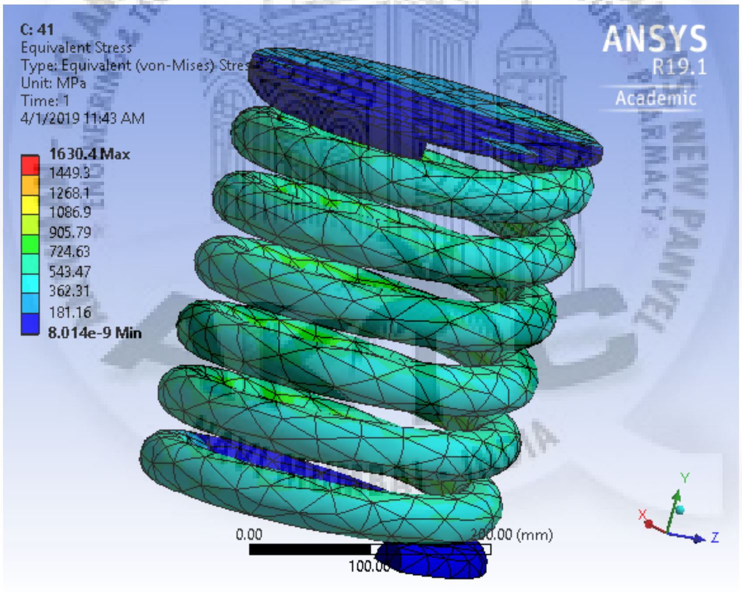



**Figure 4.20:** Equivalent Stress(Von-Moises)for 41 KN

Equivalent Stress(Von-Moises)=354.56 $N/mm^2$

### 4.4.3 Load Test Results:

The above figure 4.21 shows the Load Testing of various springs done by Indian Railways.The above fig. also shows the load testing done on ICF Bolster spring 13T.

LOAD DEFLETION TESTING AND GROUPING OF COIL SPRING

| STOCK | WIRE DIA | NO,OF COIL | FREE HIGHT | TEST LOAD | ACCEPTABLE HIGHT UNDER TEST LOAD | | GROUP AS LOAD SPG HEIGHT YELLOW A | | BLUE B | | GREEN C | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICF AXLE. 13 T | 33.6 | 6.75 | 360 | 2000 | 279 | 295 | 279 | 284 | 285 | 289 | 290 | 295 |
| ICF BOLSTER 13 T | 42 | 5.75 | 385 | 3300 | 301 | 317 | 301 | 305 | 306 | 311 | 312 | 317 |
| A/C AXLE 16 T | 33.6 | 6.75 | 375 | 2800 | 264 | 282 | 264 | 269 | 270 | 276 | 276 | 282 |
| A/C BOLSTER 16T | 42 | 6 | 400 | 4800 | 291 | 308 | 291 | 296 | 297 | 303 | 304 | 308 |
| ICF POWERCAR AXLE | 37 | 6.75 | 360 | 3000 | 277 | 293 | 277 | 282 | 283 | 288 | 289 | 293 |
| ICF POWERCAR | 47 | 5.5 | 386 | 6700 | 306 | 322 | 306 | 311 | 312 | 317 | 318 | 322 |
| BOLSTER | 34 | 7.75 | 386 | | | | | | | | | |
| | 39 | 5.75 | 316 | 1810 | 275 | 291 | 275 | 280 | 281 | 286 | 286 | 291 |
| CAPACITY PARCEL VAN A | 40 | 5.75 | 393 | 3300 | 278 | 294 | 278 | 283 | 284 | 288 | 289 | 294 |
| CAPACITY PARCEL VAN | 32.6 | 7.5 | 286 | | | | | | | | | |
| BOLSTER | 38 | 5.75 | 304 | 1820 | 264 | 276 | 264 | 268 | 269 | 271 | 272 | 276 |
| TREASUER AXLE | 45 | 5.75 | 481 | 5600 | 278 | 296 | 278 | 284 | 285 | 290 | 291 | 296 |
| TREASUER BOLSTER | 38 | 5 | 337 | | | | | | | | | |

**Figure 4.21:** Load Testing Chart

Thus, it can be determined that for the loading of 33000 N ,the maximum allowable height under test load is 279mm. i.e. $y_{max} = 385 - 279 = 106mm$

## 4.5 Results & Conclusion:

### 4.5.1 Comparison of Bolster Spring for different Loads:

| Load | Analytical Results | | | Ansys Results | | Load Testing |
|---|---|---|---|---|---|---|
| | Stress $N/mm^2$ | Deformation mm | Stiffness N/mm | Max. Deformation mm | Equi. Stress $N/mm^2$ | Deflection mm |
| 33000 N | 366.81 | 108.12 | 305.205 | 114.72 | 285.24 | 106 |
| 41000 N | 455.74 | 134.336 | 305.205 | 142.53 | 354.56 | - |

**Table 4.1:** Comparison of Bolster spring for Different Loads

### 4.5.2 Conclusion:

**Stress:**

As seen from the above table 4.1,it is clear that as load increases,there is a significant increase in stress developed in the spring. This can be Seen in ANSYS as well as Analytical calculations which results in FAILURE of spring.

**Deflection:**

The amount of Deflection of spring increases as load increases.
The Deflection as seen by Analytical Calculations ,ANSYS & Load testing for 33000 N load is found to be nearly equal.
The Deflection as seen by Analytical Calculations & ANSYS for 41000 N load is found to be nearly equal.
The maximum allowable Deflection for spring is found to be $y = 106mm$ from load testing results, thus for the load of 41000 N the Deflection Caused is $y_{max} = 134.336mm$(Analytical) & $y_{max} = 142.53mm$(ANSYS) ,which is considerably larger than design conditions.
Hence,this might Result in FAILURE of spring.

# Chapter 5

# PROPOSED SOLUTIONS

## 5.1 Change Mean Diameter(D),Free Height,No. of Coils (USE AC BOLSTER SPRING):

### 5.1.1 Loads:

Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 5.1.2 Spring Space:

Wire Diameter = 42mm
Outer Diameter = 282mm
Mean Diameter = 240mm
No. of coils = 6
spring constant: $c = D/d = 240/42 = 5.7142$
Free Height = 400mm

### 5.1.3 Analytical Calculations of AC Bolster Spring Calculation Part:

**Allowable/Designed Stress:**

$Load = P = 48000N$(As seen from 4.21, AC Bolster 16T)
Wahl's stress factor:

$$k_s = \frac{4 \times c - 1}{4 \times c - 4} + \frac{.615}{c}$$
$$k_s = 1.2667$$

Design Stress:

$$[\tau_d] = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

$$[\tau_d] = 1.2667 \times \frac{8 \times 48000 \times 5.7142}{\pi \times 42^2}$$

$$[\tau_d] = 501.547 N/mm^2$$

Load=$P = 41000N$

Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$

$$q = \frac{79300 \times 42^4}{8 \times 240^3 \times 6}$$

$$q = 371.87 N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$

$$y_{max} = \frac{8 \times 41000 \times 240^3 \times 6}{79300 \times 42^4}$$

$$y_{max} = 110.225 mm$$

Induced Stress:

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

$$\tau_{ind} = 1.2667 \times \frac{8 \times 41000 \times 5.7142}{\pi \times 42^2}$$

$$\tau_{ind} = 428.405 N/mm^2$$

As,

$$\tau_{ind} = 428.405 N/mm^2 > [\tau_d] = 501.547 N/mm^2$$

Design is SAFE.

### 5.1.4 ANSYS Results of AC Bolster Spring for Load of 41000 N:

**Total Deformation:**

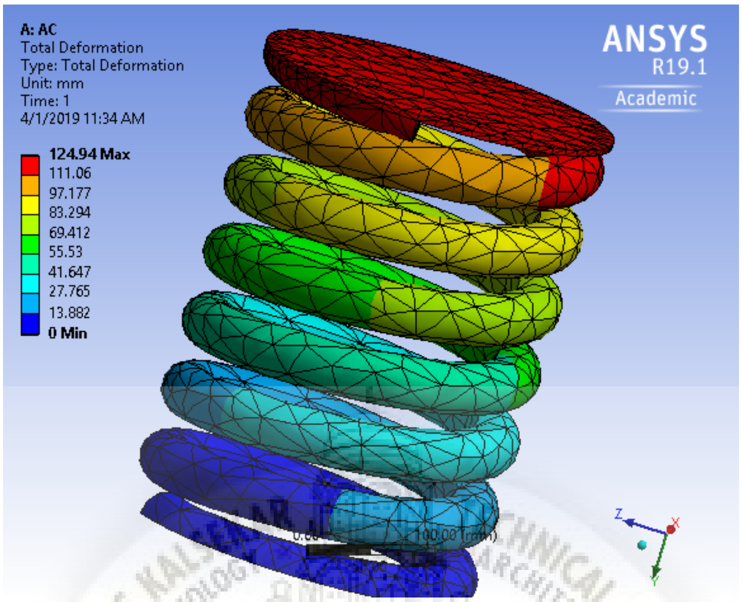



**Figure 5.1:** Total Deformation for AC Bolster Spring

Total Deformation=124.94 mm

**Equivalent Stress(Von-Moises):**

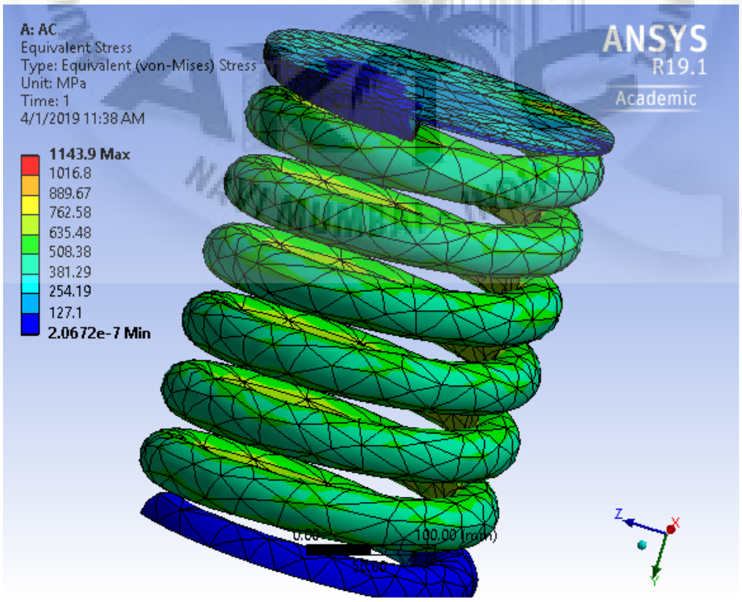



**Figure 5.2:** Equivalent Stress(Von-Moises) for AC Bolster Spring

Equivalent Stress(Von-Moises)=370.07 $N/mm^2$

## 5.2 Only Increase the Wire Diameter of Bolster Spring:

### 5.2.1 Loads:

Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 5.2.2 Spring Space:

Wire Diameter = 45mm
Outer Diameter = 302mm
Mean Diameter = 260mm
No. of coils = 5.75
spring constant: $c = D/d = 260/45 = 5.777$
Free Height = 385mm
Wahl's stress factor:

$$k_s = \frac{4 \times c - 1}{4 \times c - 4} + \frac{.615}{c}$$
$$k_s = 1.2634$$

**Allowable/Designed Stress:**

Assuming,Average service
no. of cycles $\geq 10^4 \leq 10^6$

$$[\tau_d] = .359 \times \sigma_u$$
$$[\tau_d] = .359 \times \frac{1735}{d^{\cdot 1}}$$
$$[\tau_d] = .359 \times \frac{1735}{45^{\cdot 1}}$$
$$[\tau_d] = 425.81 N/mm^2$$

Load=$P = 41000N$
Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$
$$q = \frac{79300 \times 45^4}{8 \times 260^3 \times 5.75}$$
$$q = 402.203 N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$

$$y_{max} = \frac{8 \times 41000 \times 260^3 \times 5.75}{79300 \times 45^4}$$

$$y_{max} = 101.9385mm$$

Induced Stress:

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

$$\tau_{ind} = 1.2634 \times \frac{8 \times 41000 \times 5.777}{\pi \times 45^2}$$

$$\tau_{ind} = 376.31N/mm^2$$

As,

$$\tau_{ind} 376.06N/mm^2 > [\tau_d] = 425.81N/mm^2$$

Design is SAFE.

### 5.2.3 ANSYS Results of d45D260 Bolster Spring for Load of 41000 N:

**Total Deformation:**

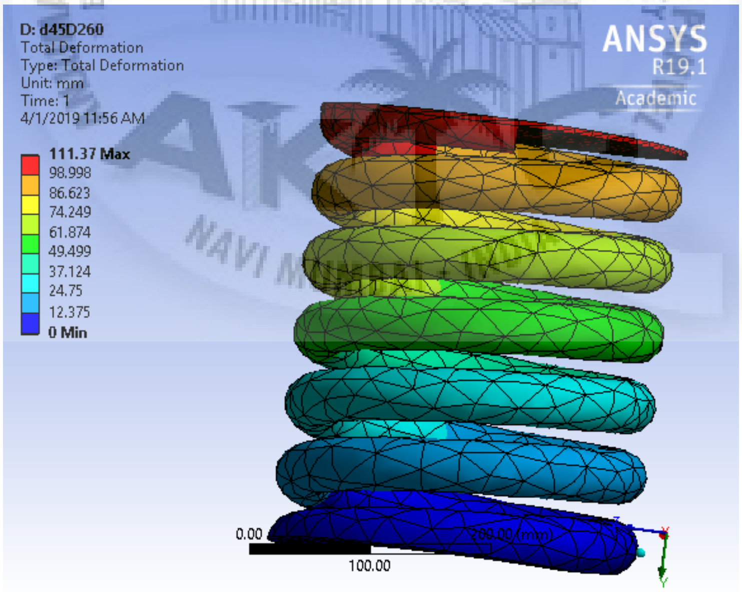



**Figure 5.3:** Total Deformation for d45D260 Bolster Spring

Total Deformation=111.37 mm

**Equivalent Stress(Von-Moises):**

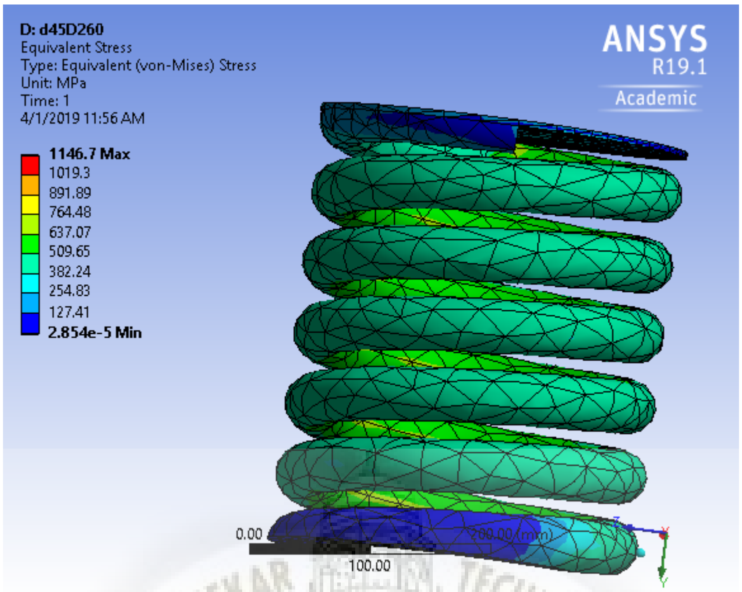



**Figure 5.4:** Equivalent Stress(Von-Moises) for d45D260 Bolster Spring

Equivalent Stress(Von-Moises)=353.32 $N/mm^2$

## 5.3 Increase the Wire Diameter & No. of Coils of Bolster Spring (d45270n6):

### 5.3.1 Loads:

Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 5.3.2 Spring Space:

Wire Diameter = 45mm
Outer Diameter = 312mm
Mean Diameter = 270mm
No. of coils = 6
spring constant: $c = D/d = 270/45 = 6$
Free Height = 385mm
Wahl's stress factor:

$$k_s = \frac{4 \times c - 1}{4 \times c - 4} + \frac{.615}{c}$$

$$k_s = 1.2525$$

**Allowable/Designed Stress:**

Assuming,Average service
no. of cycles $\geq 10^4 \leq 10^6$

$$[\tau_d] = .359 \times \sigma_u$$
$$[\tau_d] = .359 \times \frac{1735}{d \cdot 1}$$
$$[\tau_d] = .359 \times \frac{1735}{45 \cdot 1}$$
$$[\tau_d] = 425.81 N/mm^2$$

Load=$P = 41000N$
Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$
$$q = \frac{79300 \times 45^4}{8 \times 270^3 \times 6}$$
$$q = 344.184 N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$
$$y_{max} = \frac{8 \times 41000 \times 270^3 \times 6}{79300 \times 45^4}$$
$$y_{max} = 119.12 mm$$

Induced Stress:

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$
$$\tau_{ind} = 1.2525 \times \frac{8 \times 41000 \times 6}{\pi \times 45^2}$$
$$\tau_{ind} = 387.46 N/mm^2$$

As,

$$\tau_{ind} 387.46 N/mm^2 > [\tau_d] = 425.81 N/mm^2$$

Design is SAFE.

### 5.3.3 ANSYS Results of d45D270n6 Bolster Spring for Load of 41000 N:

**Total Deformation:**

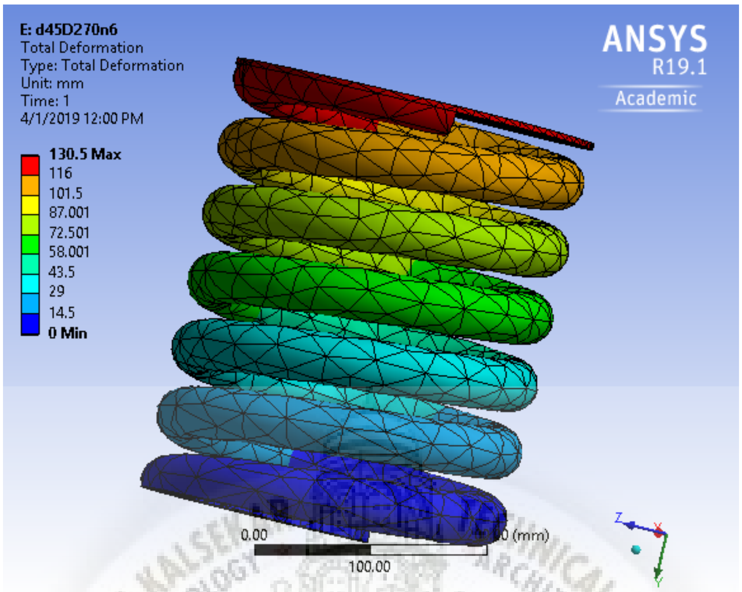



**Figure 5.5:** Total Deformation for d45D270n6 Bolster Spring

Total Deformation=130.5 mm

**Equivalent Stress(Von-Moises):**

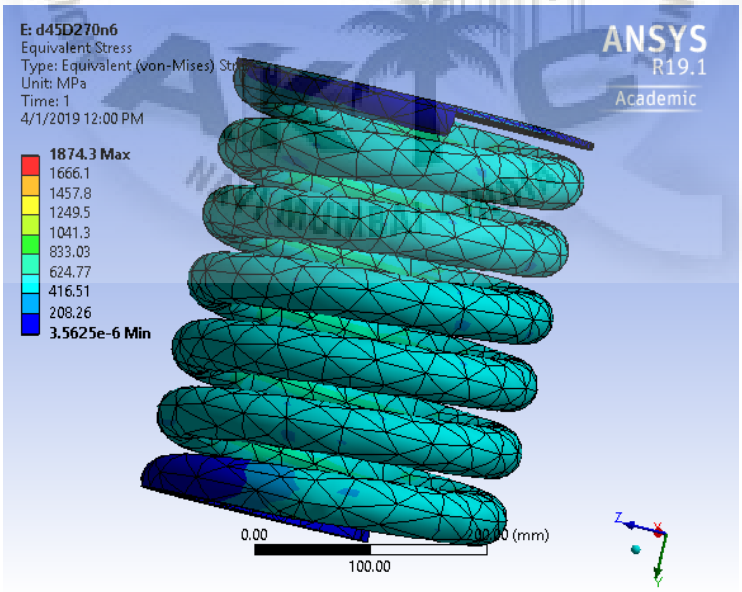



**Figure 5.6:** Equivalent Stress(Von-Moises) for d45D270n6 Bolster Spring

Equivalent Stress(Von-Moises)=372.24 $N/mm^2$

## 5.4 Increase the Wire Diameter & No. of Coils of Bolster Spring (d45270):

### 5.4.1 Loads:

Considering,the increased load due to introduction of Bio-Toilets & increased Weight due to increased passengers & luggage equal to 8 kN.
A load of 41 KN is applied on top of the spring for increased loading calculation.

### 5.4.2 Spring Space:

Wire Diameter = 45mm
Outer Diameter = 312mm
Mean Diameter = 270mm
No. of coils = 5.75
spring constant: $c = D/d = 270/45 = 6$
Free Height = 385mm
Wahl's stress factor:

$$k_s = \frac{4 \times c - 1}{4 \times c - 4} + \frac{.615}{c}$$
$$k_s = 1.2525$$

**Allowable/Designed Stress:**

Assuming,Average service
no. of cycles $\geq 10^4 \leq 10^6$

$$[\tau_d] = .359 \times \sigma_u$$
$$[\tau_d] = .359 \times \frac{1735}{d^{\cdot 1}}$$
$$[\tau_d] = .359 \times \frac{1735}{45^{\cdot 1}}$$
$$[\tau_d] = 425.81 N/mm^2$$

Load=$P = 41000N$
Spring Stiffness:

$$q = \frac{G \times d^4}{8 \times D^3 \times n}$$
$$q = \frac{79300 \times 45^4}{8 \times 270^3 \times 5.75}$$

$$q = 359.148N/mm$$

Max. Deflection:

$$y_{max} = \frac{8 \times P \times D^3 \times n}{G \times d^4}$$

$$y_{max} = \frac{8 \times 41000 \times 270^3 \times 5.75}{79300 \times 45^4}$$

$$y_{max} = 119.12mm$$

Induced Stress:

$$\tau_{ind} = k_s \times \frac{8 \times P \times c}{\pi \times d^2}$$

$$\tau_{ind} = 1.2525 \times \frac{8 \times 41000 \times 6}{\pi \times 45^2}$$

$$\tau_{ind} = 387.46N/mm^2$$

As,

$$\tau_{ind} 387.46N/mm^2 > [\tau_d] = 425.81N/mm^2$$

Design is SAFE.

### 5.4.3 ANSYS Results of d45D270 Bolster Spring for Load of 41000 N:

**Total Deformation:**

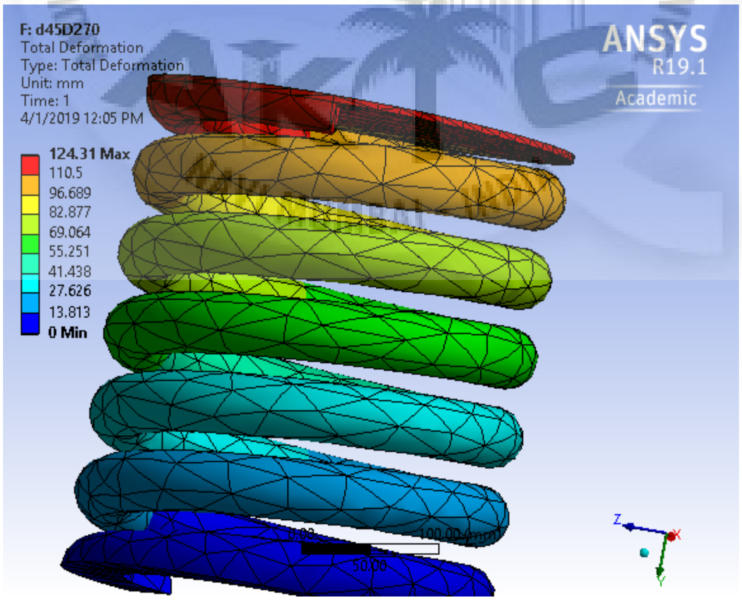



**Figure 5.7:** Total Deformation for d45D270 Bolster Spring

Total Deformation=124.316 mm

**Equivalent Stress(Von-Moises):**

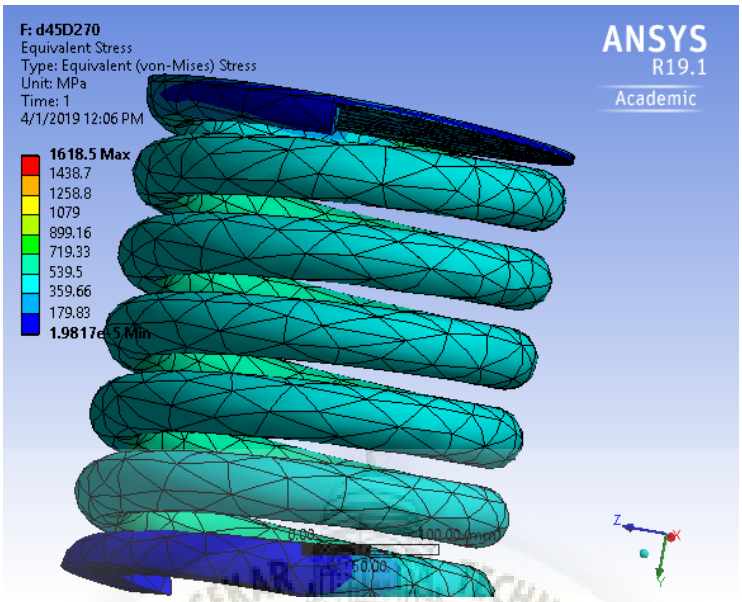



**Figure 5.8:** Equivalent Stress(Von-Moises) for d45D270 Bolster Spring

Equivalent Stress(Von-Moises)=378.64 $N/mm^2$

# Chapter 6

# RESULTS & CONCLUSION

## 6.1 Results:

| SPRING (LOAD) | Analytical Results | | | | Ansys Results | | REMARK |
|---|---|---|---|---|---|---|---|
| | Design Stress $N/mm^2$ | Ind. Stress $N/mm^2$ | Deform. mm | Stiffness N/mm | Max. Deform. mm | Equi. Stress $N/mm^2$ | |
| d42(31000) | 386.829 | 366.81 | 108.12 | 305.205 | 114.72 | 285.24 | SAFE |
| d42(41000) | 386.829 | 455.74 | 134.326 | 305.205 | 142.53 | 354.56 | UNSAFE |
| AC | 501.547 (48000) | 428.405 | 110.225 | 371.87 | 124.94 | 370.07 | OPTIMUM |
| d45D260 | 425.81 | 376.31 | 101.938 | 402.203 | 111.37 | 353.32 | |
| d45270n6 | 425.81 | 387.46 | 119.72 | 344.134 | 130.5 | 372.24 | |
| d45D270 | 425.81 | 387.46 | 114.158 | 402.20 | 3124.31 | 378.64 | |

**Table 6.1:** Comparison of Various Bolster spring

## 6.2 Conclusion:

### 6.2.1 Stress:

As seen from the above table 6.1,it is clear that as for the Present load of 41000 N,all the proposed Spring have induced Stress less than the Allowable/Design Stress. This can be Seen in ANSYS as well as Analytical calculations which results in reduced Failure of spring.

### 6.2.2 Deformation:

The amount of Deformation of all the Proposed springs are well within the limits of Design criteria.
The deformation of spring d45D270n6 is high compared to rest of the springs,this is due to the fact that this spring has the lowest stiffness value compared to all other proposed springs. The Deflection as seen by Analytical Calculations & ANSYS for 41000 N load is found to be nearly equal for all the Proposed Springs.

### 6.2.3 Comparing the Results based on Max. Deformation & Stiffness:

According to the above table 6.1,it is clear that the springs with highest stiffness are spring d45D260 & d45D270 with both having $q = 402.20N/mm$,this shows that for 1mm deformation of these spring a load of 402.02 N will be required.Which is good but as we know as stiffness increases, so does hardness because stiffness and hardness are the same in springs.

So for an Ideal spring, the deformation and stiffness shouldn't be too large.
This can be observed in AC spring proposed.
Thus,the ideal solution to our problem would be to switch the use of AC bolster spring over to general ICF coaches.this would not only be less costly than the current cost of replacing & maintaining old ICF coach spring but would be economical as this spring is already in use ,so the manufactures wouldn't have to manufacture new one which would cost them a lot more time & money in R.D along with testing process.

# Chapter 7

# FUTURE SCOPE

- Design optimization can be carried out either by changing material type or changing the design of spring. The research could throw light on why the springs fail early and why they break only at the inactive coil. The study could also present suggestions to increase the life of the spring.
- Springs designed for higher load (Parcel Van Coaches) can be used in place of spring from 13T coaches.
- Further study to optimize 16T A/C coaches can be carried out using this study as basis.
- A Study on how to use Air-spring in place of Bolster spring can be carried with the view point as to increase the air pressure required for the smooth working of Air-spring as well as the Air brakes.
- The present work has been more focused towards FEM analysis for the structural strength of the machine components. A lot of work can be carried out on the structural behaviour considering the machine components made up of machine grade steels or high strength alloys, along with the trend of change in cost of material and cost of manufacturing.

# References

[1] Wikipedia *https : //en.wikipedia.org/wiki/ICFBogie*

[2] Maintenance Manual for BG Coaches of ICF design, Indian Railway, 2015.

[3] Handbook on Bogie Mounted Brake system for ICF Coaches, Indian Railway, 2015.

[4] Failure Analysis of a Helical Compression Spring
Amitesh1, Prof V. C. Kale2, Prof K. V. Chandratre3, 2016

[5] Failure Investigation of Axle Box spring pf railway 16T coaches
Rohan Joshi, Sachin Chaudhari, Dhanraj Choudhari, Pratik Chaugule, 2015

[6] The Study of Premature Failure of Springs Used In Railway Coaches M.Sudhakar Reddy,B.Madhusudhan Reddy, 2013

[7] Failure Analysis of Inner Suspension Spring of Railway Engine: A Case Study Manoj A. Kumbhalkar, Prof. Y. L. Yenarkar, 2011

[8] Static analysis of a primary suspension spring used in locomotive
K Pavan Kumar , S Praveen Kumar and G Guru Mahesh , 2013

[9] Investigation on Reduction in Premature Failure of Locomotive Coil Springs B. Praveen kumar and P. Sampath Rao , 2014

[10] A Review on Primary Suspension of ICF Bogie
Gupta Manav, Jaiswal Rohit , Kadam Onkar,and Sharma Sanskar, 2015